Energy Deposition in MICE Absorbers and Coils

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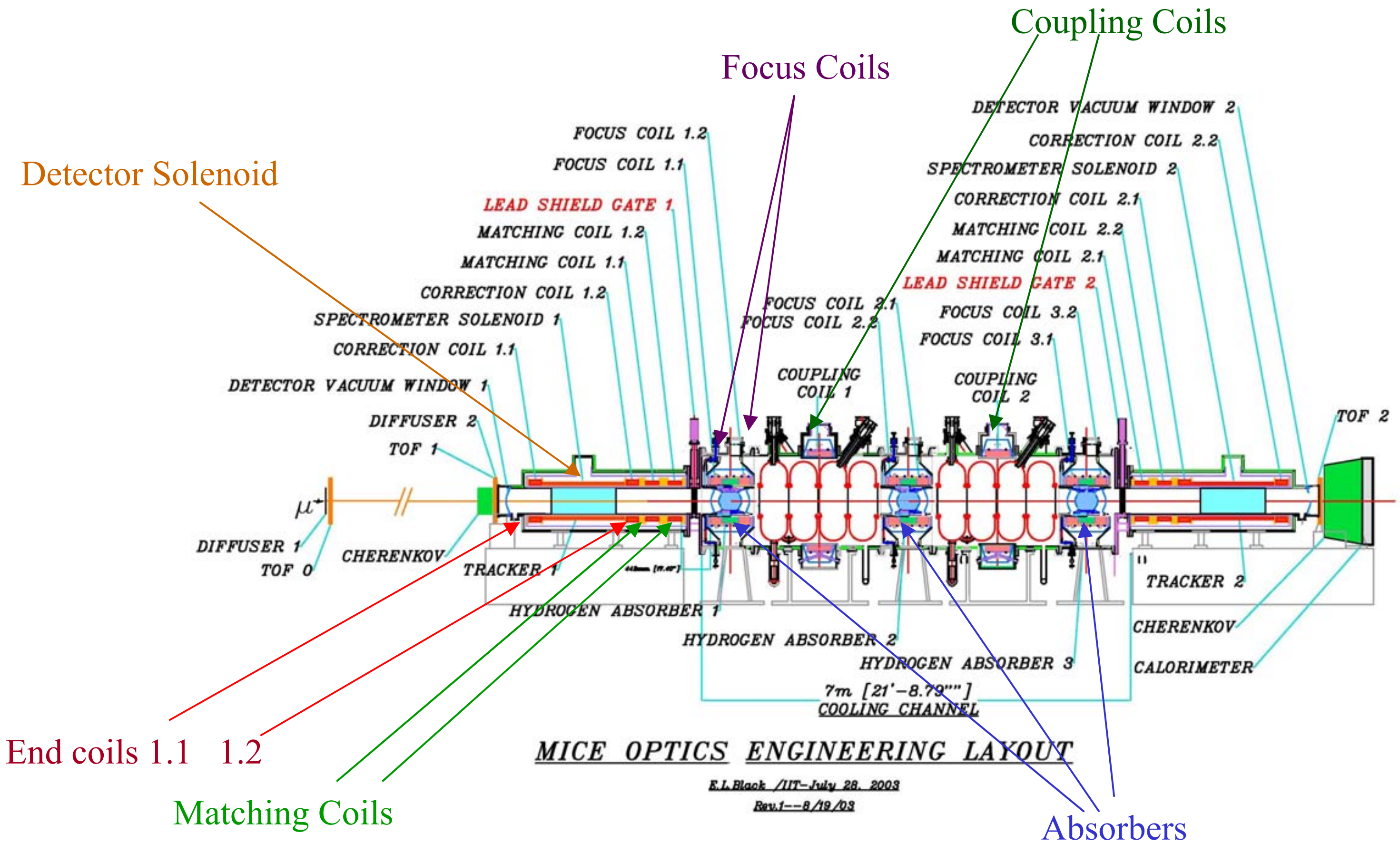
Energy Deposition – An Application for G4Mice

- We would like to estimate how much energy is deposited in magnet coils and the hydrogen absorber.
- Most of the energy deposited will come from the part of the beam that is not interesting to us:
  - Pions and protons in the beam since they dominate good muons.
  - Electrons and photons from RF.
  - The halo of the beam is particularly interesting since it is likely to be in the vicinity of the coils.
- In order for this study to be meaningful we need to normalize to something so that we can calculate something like *joules per pulse*.
- These calculations could also be done with MARS.
  - We would welcome verification of these results.

G4Mice Glossary of Terms

- VirtualDetector:
  - This is a detector volume that is place for the purpose of making histograms of track variables that pass through it.
    - This is (will be) used for calculating emittances at various planes along the MICE channel. (This is not the subject of today's talk)
- SpecialVirtualDetector:
  - Special case of a virtual detector that descends (*hangs off*) the coil and absorber volumes to histogram the energy deposited in those volumes.
    - These SpecialVirtualDetector volumes can be subdivided so as to force the step size to be small enough that the hits are deposited locally.

MICE Engineering Layout



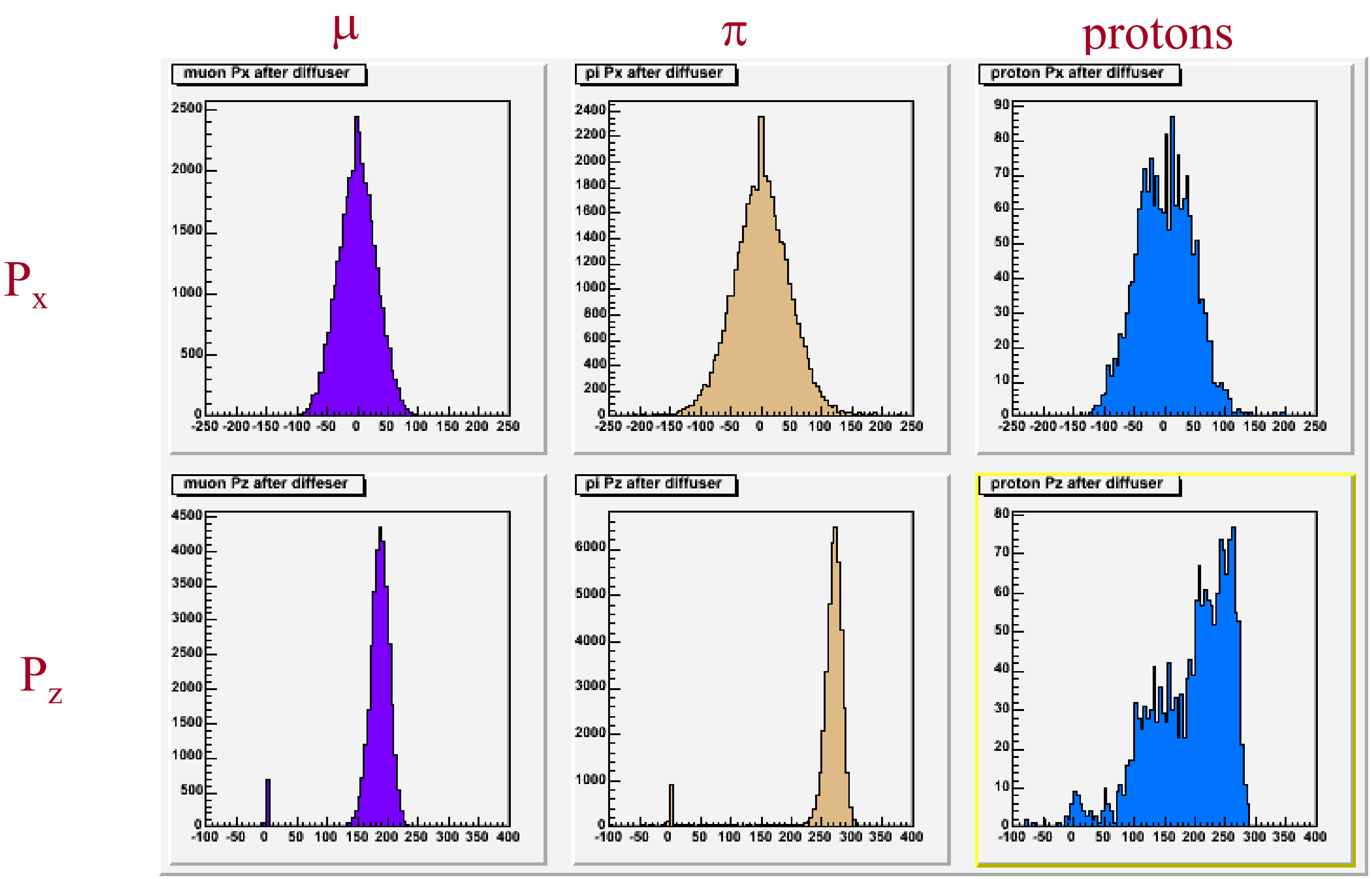
Beam and Normalization

- We will approximate our input beam to be the output beam of the beamline described by Tom Roberts (Sept 24, '03)
- We will start the beam at Diffuser 1. The number of π and μ per second are given in table below.
- The beam description at Diffuser 1:
  - $\sigma_X=\sigma_Y=200$ mm; $\sigma_{X'}=\sigma_{Y'}=0.15$ radians; no correlations
  - $\langle E_\pi^{kin}\rangle=178$ MeV; $\Delta E/E|_\pi \approx 0.05$; $\langle E_\mu^{kin}\rangle=121$ MeV; $\Delta E/E|_\mu \approx 0.1$

Quantity	*Value*
Protons/sec in accelerator	3.7×10^{16}
Protons/sec on target	1.7×10^{12}
Pions/sec in Beamline Acceptance	3.0×10^{6}
Pions at Diffuser 1	11100
Muons at Diffuser 1	25400
Muons Through Detector	215

- Note that this beam is very inefficient since most of the particles will not get into the detector channel. We are interested in getting a reasonable approximation to the halo

Momentum Distribution at Diffuser 1 (Seen at TOF1 which immediately follows)

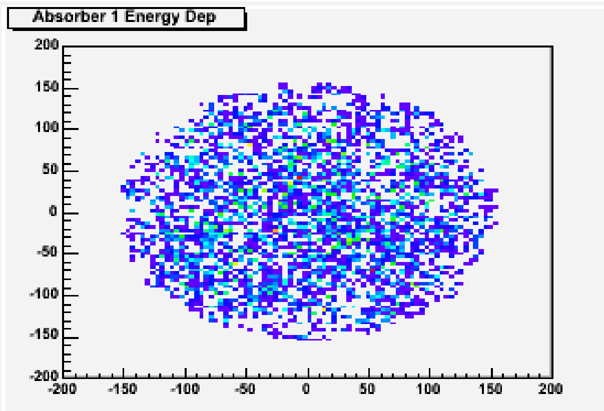


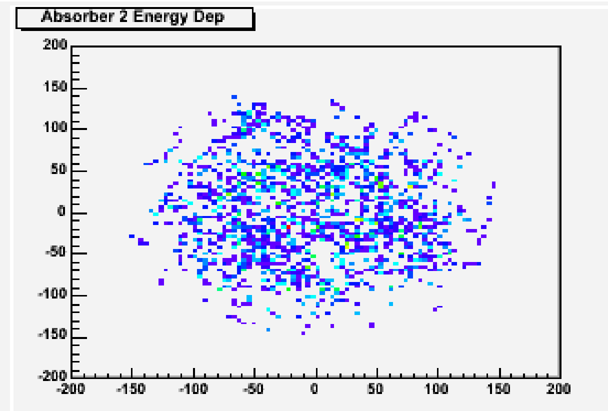
P_x and P_y have similar distributions

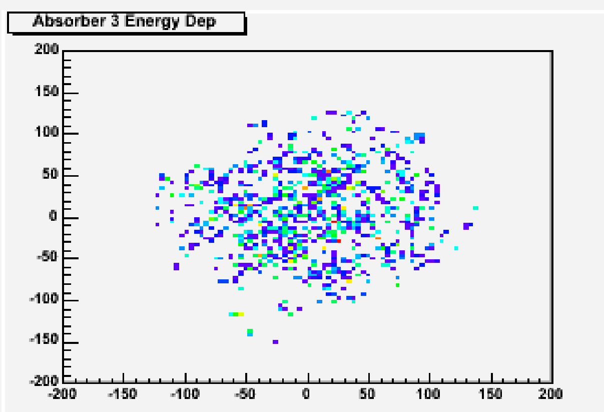
Most protons are lost in diffuser

Those that get through have larger divergence

Distribution of Deposited Energy in the Three Absorbers

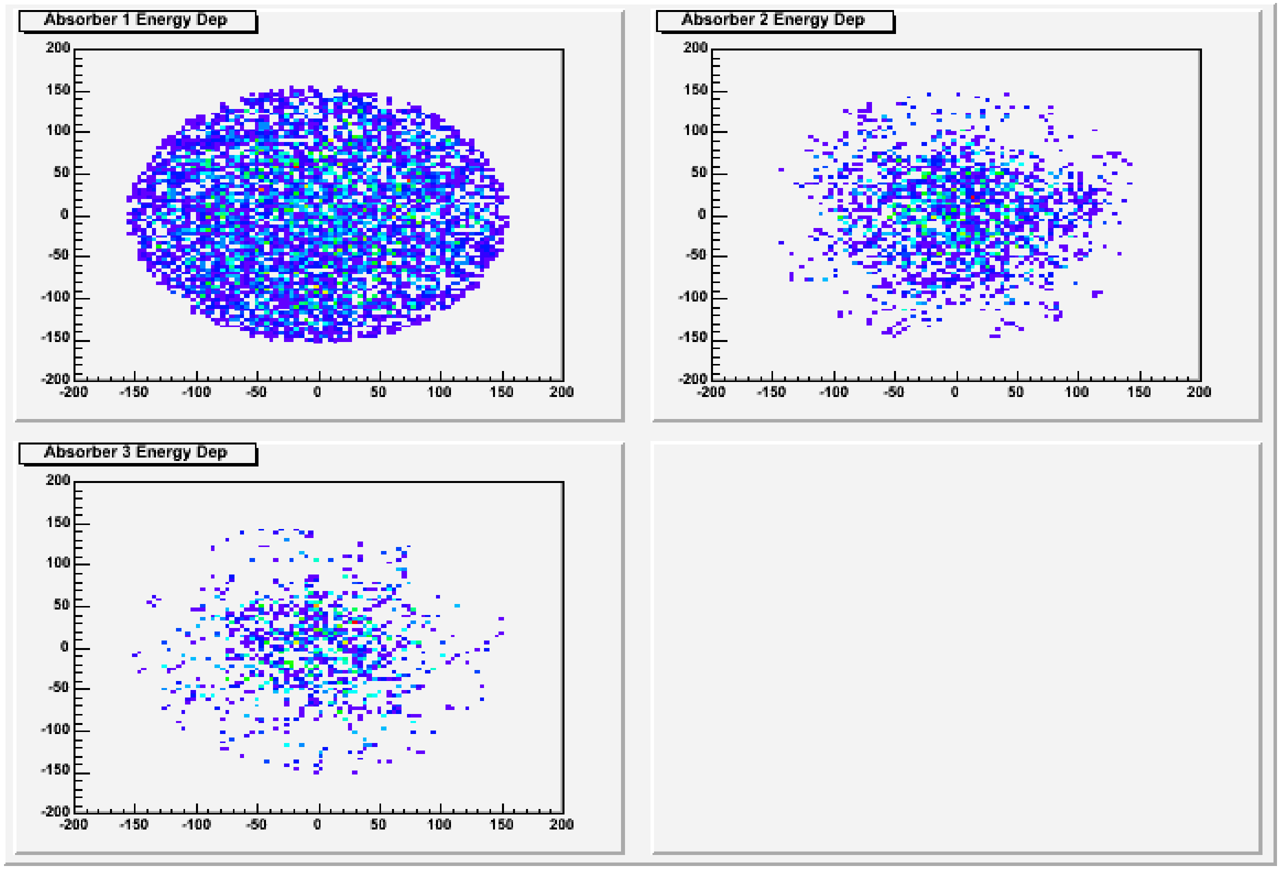




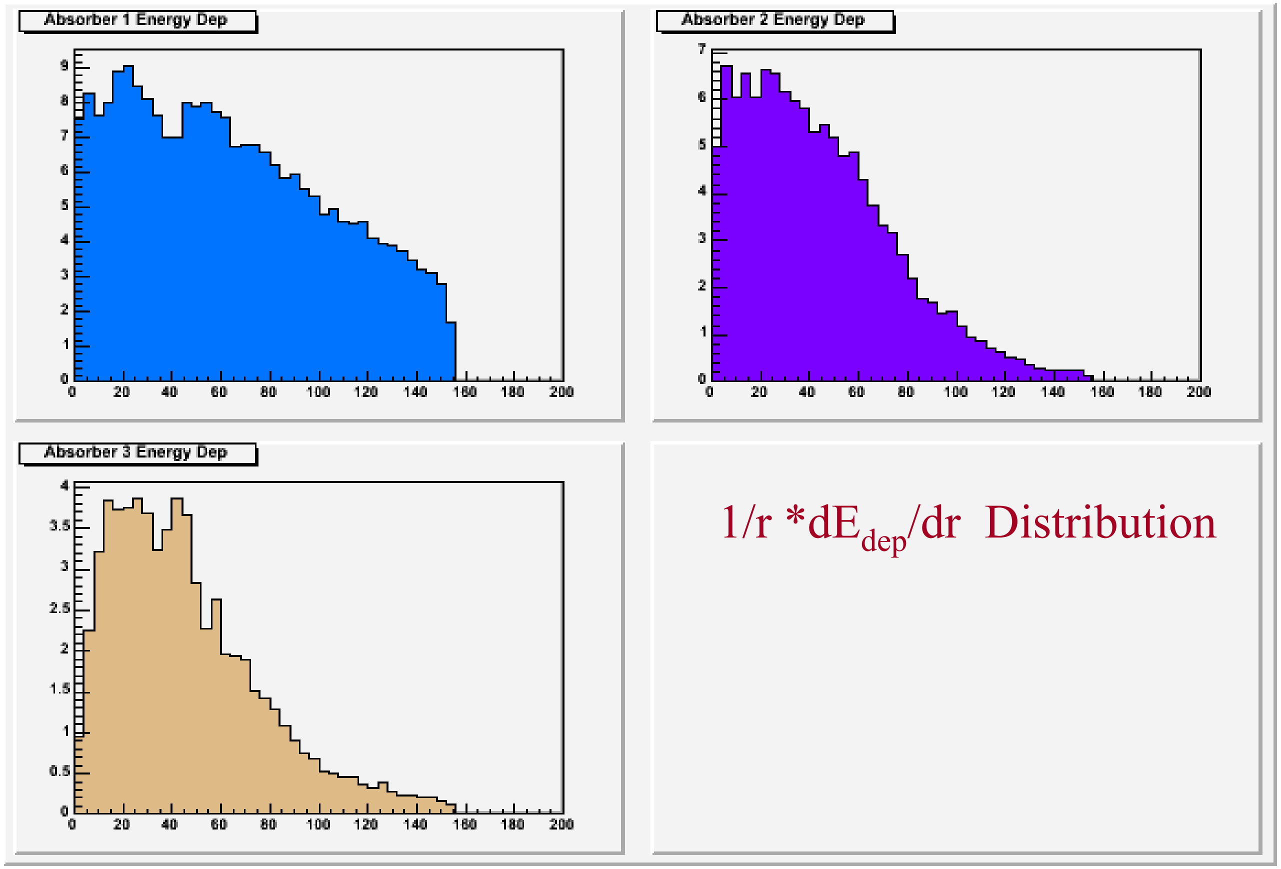


- Energy is integrated over Z
- We will discuss normalization elsewhere.
- This plot shows energy deposited by pions

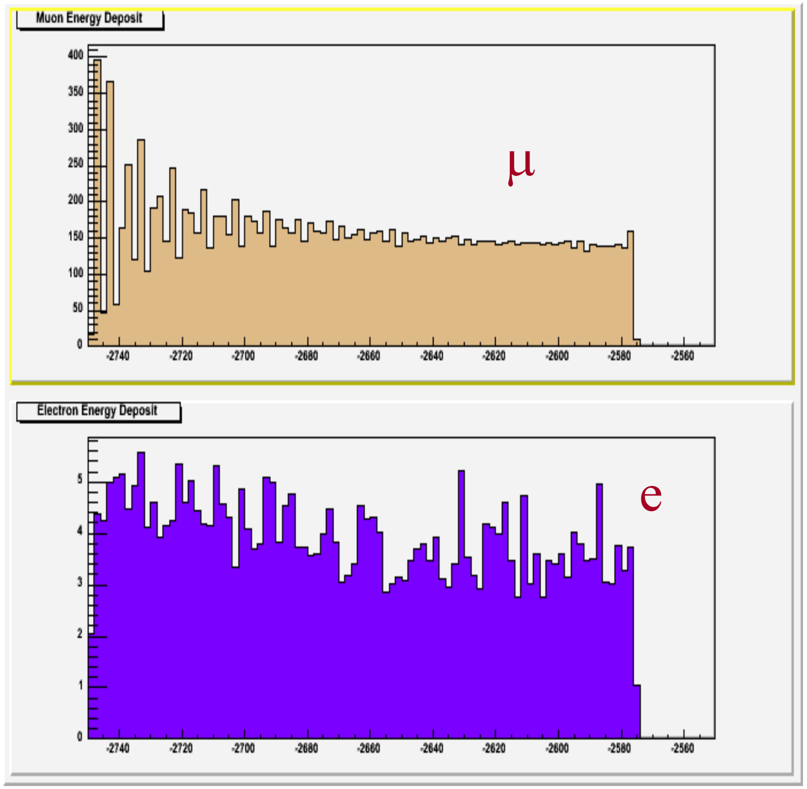
Absorber Energy Deposit Distribution for Muons



Radial Distribution of E_{dep} Density for Muons



Longitudinal Distribution of Energy in Absorber 1



- Figure shows the energy deposition along *z* for μ (upper figure) and *e* (lower figure) in absorber 1.
- Electrons are from muon decays.
- The muon distribution shows evidence of finite step size imposed by user (me).
  - Geant tends to want to take large step sizes in H_2 comparible to the size of the absorber

Total Energy Deposited in the Absorbers

- Below are the results for energy deposited in the absorbers from a sample of tracks passed through G4Mice:
  - Sample of 317271 pions at Diffuser 1.
  - Sample of 384098 muons at Diffuser 1.
- The power is the energy deposited in the absorber in pico-joules/sec normalized to Tom Roberts' beam.

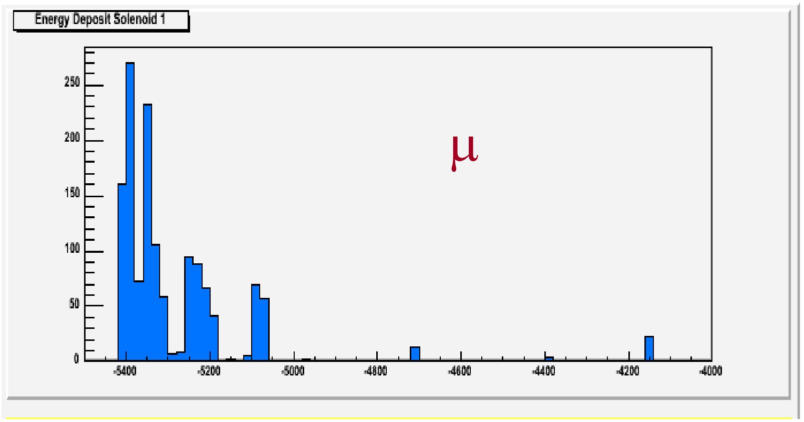
Absorber	Pions			Muons		
Number	Hits/sec	E_{Dep}/sec (MeV/sec)	Power (picoWatts)	Hits/sec	E_{Dep}/sec (MeV/sec)	Power (picoWatts)
1	319	967	154	942	2888	464
2	139	440	70	323	1006	161
3	87	258	41	162	507	81

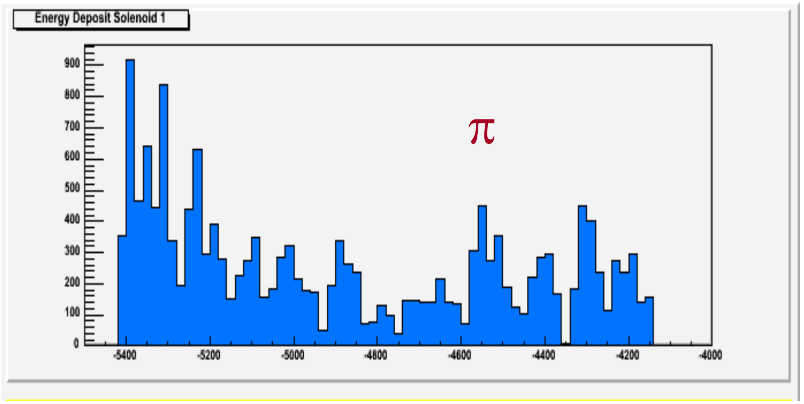
Energy Deposited in Magnet Coils

- Below are the particle hits and associated energy deposit in the magnet coils. The coils listed below are those with the most significant energy depositions.
- These are very small numbers. If we imagined that all of this energy were deposited at one location in the coil we would not quench a magnet:
  - Quenching requires *millijoules* deposited in ~1/100 sec with coils at approximately 90% of *short sample* current.
    - We aren't anywhere near that.

Coil	Pions			Muons		
Number	Hits/sec	E_{Dep}/sec (MeV/sec)	Power (picoWatts)	Hits	E_{Dep} (MeV)	Power (picoWatts)
Focus 1.1	56	667	107	873	412	66
Match 1.1	31	349	56	2468	1002	160
Solenoid 1	58	582	93	282	91	15
EndCoil 1.1	305	3962	634	715	8138	1300
Total	488	5953	952	961	10420	1670

Deposition of Energy in the Upstream Detector Solenoid





- Upper figure shows the deposition of energy from μ in the upstream detector solenoid coils.
  - Energy is deposited in upstream part.
- Lower figure shows energy deposition for π in the same coils.

What about Protons?

- We see approximately 10× as many protons produced on target as pions over the momentum range.
  - We should have 10× as many protons as $\mu+\pi$ going into diffuser 1.
  - We have seen that proton angular distribution is broader leaving the diffuser.
    - We expect fewer protons to get into the channel.
    - The protons main deposit energy in the upstream end coil

Coil	Hits/sec	Deposited Energy (MeV/sec)	Power picoJoules/sec
End Coil 1.1	763	12100	1940

Model for RF Induced Background

- The table below lists the parameters for the RF background that Yağmur gave me as representative.
  - I have not had time to understand these parameters well enough to know what I should be using.
    - We are concerned with energy deposition – not detector background.
  - Anyway these are what I used.

Parameter	Value
Source particles	γ
Photon Model	Uniform (?)
Number of Photons per Muon	20
Photon Energy	10 MeV
Photon Direction	Both +Z and –Z
Source Centered at	0 (Absorber 2)
Emission Radius	15 cm
Time Window	100 ns (not associated to beam)

RF Induced Background

- There is background induced from the RF cavities. This is more difficult to quantify.
  - Using the description in G4Mice with Yagmur's recommended parameters we can make an estimate. See table below.
  - This is likely to be an important source of energy deposited in the absorbers.

Coil/Vessel	Hits/sec	Deposited Energy (MeV/sec)	Power picoJoules/sec
Absorber 1	17546	7337	1172
Absorber 2	19774	8386	1342
Absorber 3	18552	7879	1260
End Coil 1.1	490	5583	893
Matching 1.1	102	956	153
Matching 1.2	76	732	117
Focus 1.1	15	169	27
Focus 1.3	25	288	46

Concluding Caveats

- These results are *extremely preliminary* at this point.
  - There are likely to be errors both in the program and my understanding.
- These calculations are without RF.
  - It ignores disruption of beam from the RF.
  - Initial estimates of X-rays and electrons background produced by RF are shown.
    - These are preliminary.
    - These have a large contribution to the absorbers